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DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150591

PROTOTYPE SOLAR HEATED HOT WATER SYSTEMS AND DOUBLE-WALLED HEAT EXCHANGERS (A Collection of Quarterly Reports)

Prepared by

Elcam, Incorporated
5330 Debbie Lane
Santa Barbara, CA 93111

Under Contract NAS8-32245 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy



(NASA-CR-150591) PROTOTYPE SOLAR HEATED HOT
WATER SYSTEMS AND DOUBLE-WALLED HEAT
EXCHANGERS: A COLLECTION OF QUARTERLY
REPORTS Contractor Report, Sep. 1976 - Dec.
1977 (Elcam, Inc., Santa Barbara, Calif.)

N78-21591

Unclas

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U.S. Department of Energy



Solar Energy

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1. REPORT NO. DOE/NASA CR-150591	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.	
4. TITLE AND SUBTITLE Prototype Solar Heated Hot water Systems and Double-Walled Heat Exchangers (A Collection of Quarterly Reports)		5. REPORT DATE January 1978	6. PERFORMING ORGANIZATION CODE
		8. PERFORMING ORGANIZATION REPORT #	
7. AUTHOR(S)		10. WORK UNIT NO.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Elcam, Incorporated 5330 Debbie Lane Santa Barbara, CA 93111		11. CONTRACT OR GRANT NO. NAS8-32245	
		13. TYPE OF REPORT & PERIOD COVERED Contractor Report Sep 1976 - Dec 1977	
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D. C. 20546		14. SPONSORING AGENCY CODE	
15. SUPPLEMENTARY NOTES This work was done under the technical management of Mr. Mitchell Cash, George C. Marshall Space Flight Center, Alabama.			
16. ABSTRACT This report is a collection of quarterly reports from Elcam, Inc., covering progress made from September 1976 through December 31, 1977. Elcam, under NASA/MSFC Contract NAS8-32245, is developing two solar heated hot water prototype systems and two heat exchangers. This effort consists of development, manufacture, installation, maintenance, problem resolution, and system evaluation. The reports have been reformatted and the pages renumbered. A limited amount of retyping has been done, and the cost information removed.			
17. KEY WORDS		18. DISTRIBUTION STATEMENT Unclassified-Unlimited <i>William A. Brooksbank Jr</i> WILLIAM A. BROOKSBANK, JR. Mgr, Solar Heating and Cooling Project Office	
19. SECURITY CLASSIF. (of this report) Unclassified	20. SECURITY CLASSIF. (of this page) Unclassified	21. NO. OF PAGES 32	22. PRICE NTIS

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FIRST QUARTERLY REPORT

CONTRACT NAS8-32245

ELCAM, INC.

JANUARY 14, 1977

I. SUMMARY

This First Quarterly Report covers the contract period from award in late September through December 1976. It deals with the contract status, both cost and schedules, and technical performance.

II. CONTRACT

The contract is on schedule.

Outstanding Change Proposals include:

1. A proposal (CP-03) to verify the preliminary design by building the double walled heat exchanger.
2. A proposal (CP-01) to subcontract to Desert Sunshine Exposure Tests, Inc. to perform accelerated testing to system components .
3. Elcam was informed that a third change proposal (CP02) to delete a statement in the contract regarding the SDAS, has been rejected. While we have not yet received any documentation in this regard, we are in agreement with the rejection because the implications of the statement had been misunderstood.

In addition to scheduled work, two new technology disclosures were submitted. One dealt with a duplex pump and the second suggested a direct dump option for active freeze control.

III. SCHEDULES

Table 1 illustrates the schedule planned for and the status of the nineteen objectives described in the Development Plan. Note that the scheduled completion dates are established in order to transmit the finished product or report to MSFC on schedule.

Table 2 indicates the test schedule planned for the Verification Plan. Table 3 illustrates the verification schedule for those sections of the I.P.C. which require similarity or analysis.

IV. TECHNICAL PERFORMANCE

A. Work Accomplished

This section summarizes the work accomplished during the first quarter of the contract period. Details have been provided in the monthly reports. Six general areas are covered:

1. Preliminary Design - Double Walled Heat Exchanger
2. Electronics
3. Computer Simulation
4. Heat Transfer Analysis
5. Documentation
6. Operational System Checkout

1. Preliminary Design-Double Walled Heat Exchanger

This task was completed during the first month of the contract period. The final report on the task was submitted in letter form on 1 November 1976. Change Proposal CP-03 was submitted in December 1976. The preferred design involves the use of duplex Turbotec tubes in a shell. Alternative types and forms were rejected for a variety of reasons including ease of manufacture and performance.

2. Electronics

Electronic developments have proceeded along three fronts:

- a. Autocontrol Improvements: As autocontrols were installed in the field, problems surfaced which had been overlooked during the design and bench check phases. A good example of this was an intermittent chattering pump relay. The chattering was caused by a noisy ground signal resulting from a circuitous and long ground trace on the P.C. board. The problem was solved by adding a jumper to the board.

2. Electronics (continued)

- b. Manufacturing Technology: A programmed test unit was developed to verify operation and performance of the finished autocontrol unit automatically. Ten tests are performed in each cycle, and during each test, the autocontrol is checked under sixteen different input conditions. This test unit has significantly reduced the time required to bench check each unit, and has provided the means to perform a meaningful burn in period for each unit.

In addition, the test unit has been used for accelerated life testing. The unit performs over 50,000 tests (each test includes the sixteen checks) in just under seven days. Two such programs have been performed successfully: a one week (50,000 tests) line voltage program, and a two week elevated voltage (137.5 VAC) program. In both programs the autocontrol performed as planned, and in neither program did any component failure occur. Assuming as many as ten autocontrol state changes per day (each test produces a state change in the autocontrol), the two week program was equivalent to over twenty-seven years of operation.

- c. Instrumentation: In addition to the test unit described in B above, two other electronic projects were planned. A digital thermometer was designed but not built when a commercial unit became available at a reasonable price. An insolation integrater has been designed. It will be completed after delivery of the display.

3. Computer Simulation

A step by step simulation computer program named TRNSYS was developed at the University of Wisconsin under a NSF program. TRNSYS has been modified to permit simulation of any of the several possible SUNSPOT configurations - internal and external heat exchanger and direct heating systems. The modified TRNSYS is now installed on an IBM 360-75* and has been run on a CDC6400 machine. The simulation project is currently in a hold pending availability of solar and weather data from MSFC and/or the National Weather Service.

* At the University of California, Santa Barbara.

4. Heat Transfer Analysis

In order to modify TRNSYS, a heat transfer specialist was consulted. The result of these consultations has been the formulation of the heat transfer modules of TRNSYS necessary to model the internal and external heat exchanger systems, and the direct heating version of SUNSPOT.

5. Documentation

By the end of the first quarter period of the contract, the following documents had been transmitted to SMFC:

ESC-2 Verification Plan

ESC-3 Quality Assurance Plan

ESC-7a Drawing List

ESC-7b Suggested Prototype Design Review Data

ESC-7d Autocontrol Logic

ESC-7e Measurement Definitions

ESC-7f Proposed Modifications ...

ESC-7g List of Materials in Contact with Potable Water

ESC-11 Monthly Status Reports, October and November

ESC-15 Special Handling, Installation & Maintenance Tools List

ESC-18 Hazards Analysis

ESC-22 Elcam Training Program

ESC-23 Preliminary Design - Double Walled Heat Exchanger
(See letter from this office to Mr. Mitchell
Cash, dated 1 November 1976)

5. Documentation (continued)

In addition, the following documentation had been completed or had reached a reportable state:

ESC- 4 System Performance Specification COMPLETED

ESC-17 Installation, Operation and Maintenance Manuals
PRELIMINARY VERSIONS AWAITING UPDATE

ESC-7c Drawings
PRELIMINARY DRAWINGS AWAITING CHECK/APPROVAL

6. Operational System Checkout

The operational prototype at 927 N. Kellogg Ave., Santa Barbara (927 prototype) was modified into a direct heating configuration. Approximately fifteen other direct heating systems have been installed in the Santa Barbara area. The experience gained from these field installations has verified several assumptions, caused several changes in approach, and resulted in the development of the first standard installation techniques. These findings are summarized below:

- a. Fouling: After a comparable time in service (3 months) the fouling inside the collector waterways was found to be significantly less than the fouling on the internal heat exchangers.
- b. Performance: Direct heating systems have achieved higher system performance values than those achieved with internal heat exchangers. The highest performance recorded by an internal heat exchanger SUNSPOT System is 30%, achieved in April 1976. In December 1976, the 927 prototype achieved performance in excess of 50%.
- c. Flow Rate: System performance did increase with collector loop flow rate as expected. The increase is asymptotic, however, and flows in excess of 2.5 g.p.m. resulted in limit cycling of the autocontrols.

6. Operation System Checkout (continued)

d. Changes in Approach

(1) The tank manufacturer sells their ESH* model with a single 4500 watt immersion element installed in the top port. Our experience indicates that, at least in mid-winter, this level of auxilliary heating may be insufficient. Several customers have reported running out of hot water during periods of poor solar weather. Our change in approach is to leave both elements in the existing tank, but to set the lower thermostat to its lowest temperature (usually 110° F.) This assures that even during sunless periods, the top element is loaded with warm water. During normal sunny periods, the bottom element is generally not used because solar energy provides at least 110° F. in the solar storage.

(2) Because of the limit cycle control problem noted in c. above, and because flow rates of up to 4.5 gpm were recorded in direct heating configurations, a flow rate limiting device has been included in the collector loop.

(3) Internal heat exchanger configurations permit secondary heat removal in the solar tank during periods in which the CASCADE valve is energized. Direct heating systems preclude this possibility because of temperature mixing problems - i.e., if both tanks are connected to the collectors, they will both tend rapidly toward the average of their temperatures.

e. Installation Standards

(1) All standard installations have a regulated 2 gpm collector loop flow rate.

(2) The pump is installed well above the low point in the loop, and between the storage and collectors - i.e., in the cooler side.

(3) All returns to storage tanks are through the top central P & T port - an extra long T probe is required to assure its penetration into the tank proper.

* A.O. Smith Electric Solar Heater

e. Installation Standards (continued)

- (4) All returns from storage are through the drain valve port.
- (5) All CASCADE valve plumbing routes are now either to the solar tank or to the electric tank.
- (6) All tank temperature sensors are located at the bottom element port.
- (7) A check valve is installed between the collectors and the CASCADE valve to prevent thermal siphoning at night.
- (8) A check valve is installed between the electric tank outlet and the TEE junction in the collector loop. This prevents cold shorts - i.e., without this check valve, cold street water was observed short circuiting the design flow path. Instead of forcing solar heat water through the cross over path into the electric tank, the cold make up water entering at the bottom of the solar tank simply exited the solar drain port and entered the electric tank through its drain port. Thus the bottom of the electric tank could become cold even though a tankful of solar heater water was available.
- (9) The mixing valve is now installed below the top of the electric tank to preclude continuous heating of the mixing valve and thereby creating an unwanted flow of hot water into the cold line.

B. Problem Areas

It appears that the only remaining technical problem is that of providing adequate freeze protection. As stated in the proposal, the frost cycle is designed to prevent freeze damage in areas that are not normally very cold. If the night temperature averages 32° F. for 8 hours, then the energy required to operate the frost cycle on a clear night is approximately 1/3 to 1/2 of the energy that would have been collected on a clear day before. Even if all this energy is available from the solar tank, (i.e., thereby not loading the element in the electric tank) it is nevertheless lost energy.

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B. Problem Areas (continued)

Since the majority of U.S. installations will require freeze control, rather than the frost cycle approach, it has been decided to develop an adequate and suitable freeze protection system.

The details of this decision, and the planned development program are contained in document ESC-24 entitled FAILSAFE FREEZE PROTECTION. ESC-24 will be transmitted to MSFC late in January or in early February.

TABLE ONE

DEVELOPMENT PLAN SCHEDULE & STATUS - DECEMBER 31, 1976

<u>OBJECTIVE</u>	<u>SCHEDULED COMPLETION DATE</u>	<u>STATUS</u>
1.1 Meet I.P.C. Criteria	5-4-77	Procedure
1.2 Develop System Performance Spec.	1-14-77	Completed
1.3 Verify System Performance Spec.	2-21-78*	Incomplete Data
1.4 Produce Drawings and Specifications	4-1-77	Preliminary Drawings Complete
1.5 Provide Provisions to Monitor Performance		
1.6 Installation, Operation & Maintenance Manuals		Government Furnished Equipment
1.7 Hardware Certification	4-1-77	Preliminary Completed
1.8 Incorporate Auxiliary Energy System		Awaiting Contract Modification
1.9 Obtain tank manufacturers approval	4-27-77	Completed
1.10 Determine true value of Cascade	4-27-77	Completed
1.11 Determine true value of selective surface	2-21-78	Computer simulation operational
1.12 Verify or improve thermal bond efficiency	2-21-78	Computer simulation operational
	2-21-78	Test equipment in house

*Note: All 2-28-78 dates depend on MSFC approval of CP-01 in January 1977.

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TABLE ONE

DEVELOPMENT PLAN SCHEDULE & STATUS - DECEMBER 31, 1976

<u>OBJECTIVE</u>	<u>SCHEDULED COMPLETION DATE</u>	<u>STATUS</u>
1.13 Long Range Performance Predictions	Awaiting Contract Modification	
1.14 Production Cost Analysis	2-21-78	Preliminary data gathered
1.15 Investigate Improved Product	2-21-78	Incomplete
1.16 Develop Quality Control	4-27-77	Tests & plan in development
1.17 Ensure Economic Justification	2-21-78	Incomplete data
1.18 Energy Payback	2-21-78	Incomplete data
1.19 Preliminary Design of Double Walled Heat Exchanger	10-31-76	Complete

TABLE TWO

TEST SCHEDULE - VERIFICATION PLAN - DECEMBER 31, 1976

Section	Test	JAN							FEB							MAR							APR							MAY							JUN																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
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TABLE THREE

VERIFICATION SCHEDULE - DEVELOPMENT PHASE - DECEMBER 31, 1977

<u>Week of</u>	<u>I.P.C. Sections to Be Verified</u>
10 JAN	1.2.1, 1.2.2, 1.2.2, 1.2.4, 1.3.1, 1.4.1, 1.5.1, 1.6.1, 1.7.1, 1.7.4, 1.8.1
17 JAN	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.1.6, 2.1.7, 2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.5, 2.2.6
24 JAN	2.4.1, 2.4.2, 2.6.1, 2.6.3, 2.6.4, 2.7.1, 2.8.1, 3.1.1, 3.1.2, 3.2.1, 3.2.2, 3.2.3, 3.2.4
31 JAN	3.3.1, 3.3.2, 3.4.1, 3.5.1, 3.6.1, 3.7.1, 3.8.1, 3.9.1, 4.1.1, 4.1.2, 4.2.1, 4.2.2
7 FEB	4.3.1, 4.3.2, 4.5.2, 4.6.1, 4.6.2, 4.6.4, 4.7.1, 5.1.1, 5.1.2, 5.1.3, 5.1.4, 5.1.5, 5.1.6
14 FEB	5.2.1, 5.2.2, 5.2.3, 5.2.4, 5.2.5, 5.2.6, 5.3.1, 5.3.2, 5.3.3, 5.3.4, 5.4.1
21 FEB	6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.1.6, 8.3.1, 8.3.2, 11.2.2, 11.2.3, 11.3.1, 12.3.1

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SECOND QUARTERLY REPORT

CONTRACT NAS8-32245

ELCAM, INC.

APRIL 14, 1977

I. SUMMARY

This Second Quarterly Report covers the contract period from January 1, 1977 through March 31, 1977. It deals with both cost and schedule status of the contract, and reports on technical performance.

II. CONTRACT

The work schedule has been revised to provide the slippage needed to permit a U.L. program to certify or approve the equipment to be installed at the two test sites. The following milestones were informally agreed upon late in the quarter, and remain to be confirmed:

- | | |
|---|-------------------|
| 1. Prototype Design and Installation Review | 4-27-1977 |
| 2. Phoenix site Owner complete site preparation | 6-14-1977 |
| 3. First Article Review | 6-15-1977 |
| 4. Phoenix Site Delivery | week of 6-20-1977 |
| 5. SDAS representative on Phoenix site by | 6-24-1977 |
| 6. Complete Phoenix Installation | 7-1-1977 |

Outstanding Change Proposals include:

1. A proposal (CP-01) to subcontract to Desert Sunshine Exposure Tests, Inc. to perform accelerated testing of system components.
2. A proposal (CP-03) to verify the ammended double walled heat exchanger design.
3. A proposal (CP-04) clarifying matrix in Verification Plan

4. A proposal, (CP-05), calling for delivery of non-identical systems due to differences in freezing configurations.
5. A proposal (CP-06) involving preliminary analysis by U.L. of SUNSPOT System.

III SCHEDULES

Table I updates the schedule and status reported in the First Quarterly Report. The schedule established in the First Quarterly Report for the Verification Plan has slipped. An updated schedule will be provided as soon as practical.

IV TECHNICAL PERFORMANCE

A. Work Accomplished

This section summarizes the work performed during the second quarter of the contract period. Details are available in the monthly status reports. Eight general areas are covered:

1. Electronics
2. Computer Simulation
3. Documentation
4. Freeze Protection
5. Collector Design Refinement
6. U.L. Program
7. Production Tooling
8. Phoenix Installation

1. Electronics

Several important electronic developments occurred during the second quarter. The accelerated test program was completed providing evidence of high component reliability. Two CASCADE autocontrols were driven through 100 years worth of operations at normal and elevated line voltage and normal, high and low temperatures. No component failures occurred. This program was reported in ESC-25.

Adjustments were made to both hysteresis and offset values to provide for improved operating performance. Investigations continue into the development of a customized integrated circuit and into the potential importance of microprocessors

in this field. A review of thermistors was conducted and it now appears likely that they may replace the LM 3911 integrated circuit as the sensor elements.

The electronics required to operate the Direct Dump valve was developed and integrated into current model autocontrols.

2. Computer Simulation

During the second quarter, SUNSPOT/TRNSYS was installed on an IBM 360-75. Weather data were provided by MSFC. Test runs of two days duration continue to be performed in order to fine tune the program parameters in order to establish a good fit between simulated and actual performance.

A copy of F-chart was received from the University of Wisconsin.

3. Documentation

By the conclusion of the second quarter, the following documentation had been transmitted to MSFC:

- a. ESC-2 Verification Plan
- b. ESC-3 Quality Assurance Plan
- c. ESC-4 System Performance Specification
- d. ESC-6 Change Proposals 1-6
- e. ESC-7a Drawing List
- f. ESC-7b Suggested Prototype Design Review Data
- g. ESC-7c System Drawings
- h. ESC-7d Autocontrol Logic
- i. ESC-7e Measurement Definitions (Mini P.I.P.)
- j. ESC-7f Proposed Modifications fo Sunspot Cascade
- k. ESC-7g List of Materials in Contact with Potable Water
- l. ESC-8b Verification Status Summary

- m. ESC-10-1 Quarterly Report
- n. ESC-11-1,2,3,4,5,6 - Monthly Report
- o. ESC-15 Special Handling, Installation & Maintenance Tools List
- p. ESC-16 Spare Parts List
- q. ESC-17 Installation, Operation and Maintenance Manual(s)
- r. ESC-18 Hazards Analysis
- s. ESC-22 Training Program
- t. ESC-23 Double Walled Heat Exchanger
- u. ESC-24 Failsafe Freeze Protection
- v. ESC-25 CASCADE Autocontrol Accelerated Test Program

In addition, the engineering drawings and Phoenix site installation plans are ready for internal approval prior to their being shipped to MSFC.

4. Freeze Protection

The Direct Dump freeze protection technique selected for development in ESC-24 was installed on the prototype system. Both mechanical and electronic performance have continued flawlessly. Nine field installations are planned for further checkout.

A report on the concept, development and operation will be generated after planned field tests are completed.

5. Collector Design Refinements

Several improvements were made in the area of collector design:

- a. A second set of corner brackets permitted
- b. Independent backing and rear insulation, which provided for
- c. Lower material costs which in turn yielded
- d. Cost effective thicker rear insulation.

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- e. Removal of stress raising interference fits in the corners of the glasteel covers reduced stretched cover failures to zero since the fix was devised.
- f. A bakeout period during the assembly process reduced entrapped moisture and eliminated condensate inside covers.
- g. A 3/16" tempered glass cover installed on a standard collector assembly verified that glass is a potential cover for SUNSPOT collectors.

6. U.L. Program

A preliminary investigation by the Underwriter's Laboratories was approved. This will permit U.L. to plan a safety investigation. It is expected that as a result, the equipment installed in Phoenix and San Diego will have received some form of U.L. approval.

7. Production Tooling

Several production fixtures have been identified as potentially valuable in a SUNSPOT production operation. One of these was designed and built. During the first uses of the waterway jig, manufacturing time was reduced from over 40 minutes per unit, to under 20 minutes.

8. Phoenix Installation

Although known as the Phoenix installation, the first installation site to be selected is on the Arizona State University campus at Tempe. The planned unit will be a SUNSPOT model 280C rather than the model 250C originally proposed. This model change is due to the small size (30 gallon) of the water heater installed in the dwelling, and will be provided at no increase in cost to the government.

B Problem Areas

No remaining problem areas have been identified. Immediate feedback from the preliminary U.L. investigation indicates the need for some adjustments to be made in the electronic packaging, however, these will be accomplished with only minor cost and effort. It is possible that the U.L. test will provide data that require the use of glass instead of glasteel for the collector cover. This should present no problem.

TABLE ONE

DEVELOPMENT PLAN SCHEDULE & STATUS - MARCH 31, 1977

<u>OBJECTIVE</u>	<u>SCHEDULED COMPLETION DATE</u>	<u>STATUS</u>
1.1 Meet I.P.C. Criteria	5-4-77	Procedure
1.2 Develop System Performance Spec.	1-14-77	Completed
1.3 Verify System Performance Spec.	2-21-78*	Incomplete Data
1.4 Produce Drawings and Specifications	4-12-77	Review partially complete
1.5 Provide Provisions to Monitor Performance		
1.6 Installation, Operation & Maintenance Manuals		Government Furnished Equipment
1.7 Hardware Certification	4-1-77	Completed
1.8 Incorporate Auxiliary Energy System	Awaiting Contract Modification	
1.9 Obtain tank manufacturers approval	4-27-77	Completed
1.10 Determine true value of CASCADE	4-27-77	Completed
1.11 Determine true value of selective surface	5-4-77	Computer simulation operational
1.12 Verify or improve thermal bond efficiency	5-4-77	Computer simulation operational
1.13 Long Range Performance Predictions	5-4-77	Test equipment in house
1.14 Production Cost Analysis	Awaiting Contract Modification	
1.15 Investigate Improved Product	2-21-78	Preliminary data gathered
1.16 Develop Quality Control	2-21-78	Incomplete
	4-27-77	Tests & plan in development

* Note: It not appears that an independent test of the system performance specification will not be funded. Verification will be attempted during the operational test period, and perhaps at MSFC during Fall 1977.

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Table One
Development Plan Schedule & Status
March 31, 1977

Page Two

<u>OBJECTIVE</u>	<u>SCHEDULED COMPLETION DATE</u>	<u>STATUS</u>
1.17 Ensure Economic Justification	2-21-78	Incomplete data
1.18 Energy Payback	2-21-78	Incomplete data
1.19 Preliminary Design of Double Walled Heat Exchanger	10-31-76	Complete

THIRD QUARTERLY REPORT

CONTRACT NAS8-32245

ELCAM, INC.

JULY 5, 1977

I. SUMMARY

This third quarterly report covers the contract period from April 1, 1977 through June 30, 1977. It covers both the cost and schedule status of the contract, and reports on technical performance.

II. CONTRACT

The development phase of the contract was completed on schedule with the successful conclusion of the First Article Review on June 15, 1977. A revised schedule was adopted for the Phoenix installation. The installation review is now scheduled to be held on August 11, 1977.

By the end of the third quarter, all of the development phase objectives had been met. The government has accepted, but not taken delivery of the hardware.

Outstanding Change Proposals include:

CP-01 Outdoor Exposure Contract

CP-08 Proposed Underwriters Laboratories Investigation

CP-09 Training, Installation & Six Months Operational Support for Phoenix Operational Test Site

CP-10 Change to Compensation Schedule

III. SCHEDULES

The development phase of the contract was completed on schedule. Installation dates have slipped because of delayed delivery on certain GFE (SDAS and associated sensors), and because of a delay in the selection of the San Diego site.

The Phoenix installation schedule is presented below:

- a. Deliver SDAS sensors to Contractor's plant: July 25.
- b. Deliver SDAS and solar equipment to installation site: August 8.
- c. Install SDAS and solar equipment: week of August 8.
- d. Installation review: August 11

III. SCHEDULES (continued)

A tentative initial San Diego site meeting has been scheduled for August 4, 1977. No schedule has been finalized for the delivery of the double walled heat exchanger defined in Supplemental Agreement, Modification #5. It is reasonable, however, to expect delivery by September 30, 1977.

IV. TECHNICAL PERFORMANCE

A. Work Accomplished:

This section summarizes the work performed during the third quarter. Details are presented in the monthly status reports. The following nine general areas are covered:

1. Documentation
2. Electronics
3. Production Planning
4. Prototype Design Review
5. First Article Review
6. Computer Simulation
7. Phoenix Installation Planning
8. U.L. Program
9. Hardware Production

1. Documentation

By the end of the third quarter, all of the development phase documentation had been completed. The following complete list of this documentation indicates which documents have been revised:

- ESC-2, Verification Plan, 11/76, Modification CP-04
- ESC-3, Quality Assurance Plan, 12/76
- ESC-4, System Performance Specification, 1/77
- ESC-7a, Drawing List, Revised 6/77
- ESC-7b, Suggested Prototype Design Review Data, 11/76
- ESC-7d, Autocontrol Logic, 11/76
- ESC-7e, Measurement Definitions, 11/76
- ESC-7f, Proposed Modification, 11/76

ESC-7g, List of Materials in Contact With Potable Water,
 Revised 6/77
 ESC-8b, Verification Status Summary, 3/77
 ESC-8cP, Instruction to Site Owner, 4/77
 ESC-9a, Verification Status Summary, 5/77
 ESC-12a, Shipping Requirements, 6/77
 ESC-13, Qualification and Acceptance Test Procedures, 5/77
 ESC-14, Qualification Test and/or Analysis Report, 4/77
 ESC-15, Special Handling, Installation & Maintenance Tools
 List, Revised 6/77
 ESC-16, Spare Parts List, 3/77
 ESC-17, IOM Manual, Revised 6/77
 ESC-18, Hazards Analysis, 11/76
 ESC-19, Design Data Brochure, 5/77
 ESC-22, Elcam Training Program, 12/76
 ESC-23, Preliminary Design of Double Walled Heat Exchanger, 11/76
 ESC-24, Failsafe Freeze Protection, 1/77
 ESC-25, Cascade Autocontrol Accelerated Test Program, 4/77

In addition to the above textual documentation, 178 engineering specification source control drawings have been prepared.

Five additional reports will be submitted in July:

ESC-26, Direct Dump Freeze Protection
 ESC-27, Production Costing
 ESC-28, Collector Cover Freeze Damage Test
 ESC-29, Energy Payback Analysis
 ESC-30, Computer Simulation

2. Electronics

The following significant electronic developments occurred during the third quarter.

- a. The Class I and Class II circuits of the CASCADE autocontrol were separated in order to comply with U.L. requirements.
- b. The insulation integrator was completed and installed at the prototype.
- c. Several CASCADE variants were developed to provide energy management for space heating systems.

3. Production Planning
Elcam has committed to a production rate of 100 collectors per month. Production planning to meet this goal has resulted in new jig and fixture designs, new process controls and improved production organization. Because of an expected order for 3000 systems (4500 collectors) for the first year of an agreement being negotiated with a national distributor, production planning is now centering on a rate of 500 collectors per month. A production consultant has been retained to provide the experience needed to achieve this goal.
4. Prototype Design Review (PDR2)
The PDR2 was held at the Contractor's plant on April 27 and 28, 1977.
5. First Article Review
The First Article Review was held at the Contractor's plant on June 15, 1977.
6. Computer Simulation
The SUNSPOT/TRNSYS computer simulation was completed in June. The report (ESC-30) presents comparative simulated performance results for SUNSPOT CASCADE and two preheater configurations. In addition, the SUNSPOT data are compared to prototype test data.
7. Phoenix Installation
Site preparation plans were prepared by the Contractor. Instrumentation selection was coordinated with IBM directly. The SUNSPOT System which will be installed on the Arizona State University Campus in Tempe, will be a model 250-C with Direct Dump. The installation is scheduled for the week of August 8, 1977.
8. U.L. Program
A preliminary investigation was performed by U.L. representatives in April and May. Their plans for and cost estimate of the formal investigation were received in May. These formed the basis of a change proposal to authorize a modified U.L. certification program.
9. Hardware Production
The hardware required for the Phoenix installation was inspected and approved during the First Article Review on June 15. The equipment is being stored at the Contractor's plant.

B. Problem Areas

No outstanding technical problem areas have been identified.

A program problem was identified and discussed during the First Article Review. The shortage of SDAS equipment may result in a reduced test duration in Phoenix, and could require cancellation of the San Diego test. A low cost SDAS alternative was suggested for the San Diego installation in the event that an IBM SDAS was not available.

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FOURTH QUARTERLY REPORT

CONTRACT NAS8-32245

ELCAM, INC.

October 10, 1977

I. SUMMARY

The fourth quarter report covers the period from July 1 through September 30, 1977. It reports on both cost and schedule status of the subject contract and also covers technical performance.

II. CONTRACT

The most significant contract activity during this quarter was the completion of the Phoenix installation. Although poor planning and a lack of equipment and supplies resulted in an extended installation period, these difficulties were overcome through the dedicated efforts of NASA, IBM, and ELCAM staff. The equipment has performed normally since installation, and no maintenance has been required.

The double walled heat exchanger development phase has been completed and the first article is in test. The first article and the test procedures will be reviewed during the quarterly review scheduled for mid-October.

The following change proposals are outstanding:

- CP-12 Modifications to Phoenix Installation
- CP-13 Training, Installation and Six Months Operational Support for San Diego Installation Site.

Change Proposal, CP-01, Outdoor Exposure Contract has been denied.

III. SCHEDULES

The contract remains on schedule. The next milestone is the delivery of two double walled heat exchangers. This is scheduled for October. No delays are expected in this regard.

The contract is due to be completed in February 1978. In view of the January 1978 installation date expected for the San Diego site, it is anticipated that a contract extension will be negotiated.

IV. TECHNICAL PERFORMANCE

A. Work Accomplished:

In addition to the Phoenix installation, several reports were developed and/or revised. These are listed below, and are in addition to the list of documents presented in the Third Quarterly Report dated July 1977.

7e Measurement Definitions - San Diego Installation
 Measurement Definitions - Phoenix Installation
 Revised 9/1977

17 Installation, Operation, and Maintenance Manual
 Revised August 1977

26 Direct Dump Freeze Protection

27 Production Costing

28 Collector Cover Freeze Damage Test

29 Energy Payback Analysis

30 Computer Simulation

31 Snap Fin Thermal Bond Test

32 Duplex Heat Exchanger Performance Analysis

As a direct result of the preliminary investigation by Underwriters Laboratories, the Autocontrol has been completely redesigned. The new design is known as Model #150 while the old design is referred to as Model #100. Model #150 should satisfy all of the Underwriters Laboratories' requirements. It is expected that Model #150 will be available in time for the San Diego installation.

During the fourth quarter, U.S. Patent #4,052,000 was awarded to the principal investigator. This patent provides both broad system and specific detail coverage. Several foreign applications based on the U.S. patent have been filed. Additionally, a U.S. patent application was filed to cover the Freeze Protection technique.

A potential single order for 3000 systems was discussed in the Third Quarterly Report. Negotiations with the national distributor were terminated without an order being placed. Instead, Elcam has launched a marketing program of its own. Because of the very aggressive California State solar tax incentive (55% tax credit up to \$3,000) Elcam believes that a regional marketing plan will initially permit for a more controlled start-up. A slightly reduced production goal of 2000 systems has been established for the first year of series production which began on October 1, 1977.

B. Problem Areas:

No outstanding problem areas have been identified.

Initial data from the Phoenix site indicate that a potentially valuable collector performance improvement may be available through a redesign of the fin tube thermal bond. Accordingly, a test and development project has been defined.

FIFTH QUARTERLY REPORT

CONTRACT NAS8-32245

ELCAM, INC.

JANUARY 10, 1978

I. SUMMARY

The Fifth Quarterly Report covers the period from October 1 through December 31, 1977. It reports on the schedule status and technical performance of the subject contract.

II. CONTRACT

During the Fifth Quarter, the double walled heat exchanger project was successfully completed. The two deliverable hardware items were tested and shipped to IBM Huntsville.

The Fourth Quarterly Review was held at the contractor's facility. A tentative San Diego OTS installation date was selected. This date has now slipped from mid-December 1977 to February 1978. It remains tentative.

The thermal bond test grew into a performance comparison between seven candidate fin-tube arrangements. Inadequate test equipment resulted in inconclusive test data.

The Tempe OTS data were monitored. During a site visit in November, the electric element power meter was found to be miswired. This resulted in the data indicating zero electric power demand. The wiring was corrected and good data are now being generated.

A check valve in the collector loop was found to be ineffective. The resulting nocturnal radiation caused significant thermal losses from the storage tank.

The vacuum relief valve was found to be full of deposits. Fortunately the back-up vacuum relief has operated normally, providing for drain-down freeze protection when required. The deposits were transmitted to NASA - MSFC for analysis. Additional deposits have been requested by NASA.

Apparently the same material has deposited in the two tank flow meters (W100 and W101) resulting in spurious data. W100 was corrected, but W101 remains faulty. The fault is to be corrected by a software modification. A leak which developed in W100 was repaired by IBM and University staff personnel. W300 continues to provide inadequate data.

In November, the element override relay failed in the override position. This resulted in complete dependence on solar energy, and a lower electric tank average temperature for the month. The relay was replaced with an upgraded item.

The installation appears to have stabilized now, and with the exception of the flow meter problems, has operated normally since December 1, 1977.

The second phase of the U.L. program was initiated in December. A prototype Model #150 autocontrol and associated hardware and data were shipped to U.L. in Santa Clara, CA. Four Model #3200 collectors were shipped to U.L. in Northbrook, Illinois.

No Contract Modifications were received during the Fifth Quarter. CP-14, proposing routine maintenance and equipment for the Tempe and San Diego OTS was submitted in October. CP-01 (Desert Sunshine) was formally denied.

The following change proposals are outstanding, although they have been approved:

- CP-12 Modifications to Tempe OTS
- CP-13 Training Installation and Six Months' Operational Support for San Diego OTS
- CP-14 Extended Routine Maintenance and Equipment for both Tempe and San Diego OTS.

III. SCHEDULE

The contract remains substantially on the established schedule. The U.L. program restart occurred in December 1977 as planned. The Tempe OTS demonstration schedule has slipped by about three months. A resolution of this problem has not yet been determined. The San Diego OTS scheduled installation has now slipped to February 1978 at the earliest. These two slips will require at least two schedule revisions:

- a. The Tempe OTS data review date
- b. The contract completion date.

The latter may not cause any problem because CP-14 would extend the contract in any case.

IV. TECHNICAL PERFORMANCE

A. Work Accomplished

Work performed during the Fifth Quarter included:

1. Two site visits to and monitoring the data from the Tempe OTS,
2. Completion of the Duplex Heat Exchanger project including Report #ESC-35 on the tests of the heat exchanger,
3. Completion of the development phase of the Model #150 Autocontrol and restart of the U.L. program,
4. Inconclusive completion of the fin-tube comparison tests, and
5. Publication of Report #ESC-33 on Prototype Data and #ESC-34 on SUNSPOT CASCADE Operating Advantages.

B. Problem Areas

No outstanding problem areas have been identified.